Lesson: Passive Solar House Design- Grades 6th–12th *(-Adapted by Eresha Kissoon)*

This is a great way to teach students engineering. It requires them to design, create, test, refine, and communicate scientific findings. It's a great inquiry project that will keep students engaged in doing science.

Lesson Summary: Students will work in groups for one week to design and build passive solar houses after learning about insulation, window placement, thermal mass and surface colors. They will test houses for thermal gains and losses during a simulated day and night then communicate findings to class.

Time required: 250 minutes. Students' in-depth engineering design and build projects require five 50-minute periods to complete.

Objectives: Students will be able to

- Design and build a passive solar house.
- Model techniques used in passive solar heating to test and refine design.
- Communicate and present findings to the class.

Standards

Scientific Communication

The student demonstrates effective scientific communication by clearly describing aspects of the natural world using accurate data, graphs, or other appropriate media to convey depth of conceptual understanding in science; that is, the student:

a.	Represents data and results in multiple ways, such as numbers, tables, and graphs; drawings, diagrams, and artwork; and technical and creative writing.
b.	Argues from evidence, such as data produced through his or her own experimentation or by others.
c.	Critiques published materials.
d.	Explains a scientific concept or procedure to other students.
e.	Communicates in a form suited to the purpose and the audience, such as by writing instructions that others can follow; critiquing written and oral explanations; and using data to resolve disagreements.

Standard 1 Analysis, Inquiry, and Design
Scientific Inquiry
1.The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
2.Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. p. 4
3.The observations made while testing explanations, when analyzed using conventional and invented methods, provide new insights into phenomena. p. 5
Engineering Design
1.Engineering design is an iterative process involving modeling and optimization finding the best solution within given constraints which is used to develop technological solutions to problems within given constraints. p. 5

Statistics and Probability Strand

Students will collect, organize, display, and analyze data.

Organization and Display of Data

6.S.4 Determine and justify the most appropriate graph to display a given set of data (pictograph, bar graph, line graph, histogram, or circle graph)

Analysis of Data

6.S.7 Read and interpret graphs

Students will make predictions that are based upon data analysis.

Predictions from Data

6.S.8 Justify predictions made from data

Professional Development Standards

Domain 1: Planning and Preparation

Component 1c: Selecting Instructional Goals

- Suitability for diverse students

Domain 2: The Classroom Environment

Component 2a: Creating and Environment of Respect and Rapport

- Teacher interaction with students
- Student interaction

Domain 3: Instruction

Component 3a: Communicating Clearly and Accurately

- Directions and procedures

Component 3b: Using Questioning and Discussion Techniques

- Quality of questions

- Student participation

Component 3c: Engaging Students in Learning

- Representation of content
- Activities and assignments
- Grouping of students
- Instructional materials and resources
- Structure and pacing

Handouts

1. Design Challenge Handout
2. Analysis and Results Worksheet
3. Teacher Testing Setup

Vocabulary

HVAC- Acronym that stands for "heating, ventilating, and air conditioning", which is an area of design and research for civil engineers.

Insulation- Material that prevents the transfer of heat

Passive Solar Design- Using the sun's energy, the geographical climate, and the properties of different materials to heat and cool buildings.

Thermal Mass- Construction materials incorporated into passive solar design because of its high heat storage capacity. Possible materials include floors and walls made of concrete, tile, brick, masonry, stone, soil and water.

Materials

Each group needs:

- 32 x 20-inches sheet of 1/8-inch foam core board (this is one half of the standard foam core board sheet, typically available with the dimensions of 1/8-inch x 32-inches x 40-inches [.32 x 81 x 102-cm]; this is about 9 sq ft or .84 sq m)
- 1 sq ft (.09 sq m) thin clear plastic
- 4 sq ft (.37 sq m) aluminum foil
- 2 sq ft (.19 sq m) thin rubber (any kind)
- 2 sq ft (.19 sq m) black fabric (any kind)
- pencils, erasers and white or graph paper for designing and graphing
- Design Challenge Handout, one per group
- Analysis & Results Worksheet, one per group

For the entire class to share:

- hot glue guns and/or tacky glue
- scissors
- utility knife
- thumbtacks
- scotch tape
- masking tape
- protractor
- straight edge (metal ruler)
- For one testing station (you may want more than one station):
- 300-watt light bulb
- desk or clamp lamp (that can safely accommodate a 300-watt light bulb)

- floor or box fan
- ice
- bucket or plastic container (for the ice)
- thermometer
- watch or timer to determine 30-second intervals
- Teacher Testing Steps Handout

Lesson Sequence

Day 1- Direct Instruction	1. Project smartboard attachment to deliver background information 2. Goal: To design and build a one bedroom model house within the design criteria, utilizing passive solar heating techniques to warm up the house as much as possible and sustain that temperature as long as possible. 3. Assign groups and brainstorm ideas in science journal.

- Imagine if we could heat houses without the use of ANY electrical or gas heaters! Think about the positive effects it would have on people all around the world. Millions of people would be able to stay warm all through the winter, save money on energy bills, and lower the greenhouse gas emissions. Interest in passive solar design is growing rapidly because of the increasing cost of energy as well as growing concerns about global climate change. This has inspired engineers to develop new techniques for passive heating and cooling that can be more easily incorporated into existing buildings and homes.

- Of all the heating methods, passive solar offers the cheapest up-front costs, best reliability, easiest maintenance, and no ongoing demand for energy to operate. Engineers combine passive solar heating with conventional methods to reduce the need for energy-guzzling heating appliances.

- Basic principles of passive solar design have been around for centuries. In years past, Native Americans who lived in harsh desert locations built partially underground homes that kept them cool during the day and warm at night. They also built adobe homes in cliff-side caves that were chosen because the winter sun warmed them and the summer sun couldn't reach them. Today, engineers are expanding upon these principles to apply them to the many and varied homes that we all live in, so we can be efficient in our energy usage and save some money on our heating bills.

- Good passive solar design equal excellent insulation. This is true for any HVAC system, but it is especially important in passive design because passive solar heating does not produce as much heat as conventional methods. So — it is important that the heat produced is not wasted. While a number of materials exist to create well-insulated walls, ranging from spray-on foam to hay bales, it is important to remember to insulate the other parts of your house — all the places that separate the inside from the outside. These places include the roof/ceiling, and windows and doors. For example, windows let considerably more heat escape to the outside than the walls of your home.

- Windows are another important component of passive solar designs. You don't want to have too many windows for a good passive solar design. On the other hand, while a windowless building would have the best insulation, would you want to live in it? Rather than eliminate windows altogether, you can install high-quality, double-pane windows and place them in strategic locations. Double pane windows are much better insulators than single pane ones. (In fact, engineers have designed many types of high-tech windows that are helpful for good passive solar design.) For heating purposes, windows are best placed primarily on the equator-facing wall so that they can let sunlight in. Windows, placed in the right locations, can bring in the most sunlight without losing too much heat.
- Once the sunlight comes into a room, two other aspects of passive solar design become important:

- thermal mass- A good thermal mass is a material that can absorb lots of heat and release it slowly when the surrounding temperature starts to go down. A few materials with a high thermal mass are concrete, bricks and water. When used properly, these materials absorb the heat from the sunlight coming through windows and then release that heat throughout the night

- surface color- darker colors absorb more sunlight than lighter colors, for passive solar heating, we would want darker colors on the outside and inside of a building

- Using windows, darker colors, and thermal masses, we can create a passive solar heating design that warms up a house during the day and keeps it warm throughout the night. The trick comes in finding the right amount of each item to be used and integrating it into a house.

- Larger volumes of space need more heat to make the same gain in temperature as a smaller volume. So a smart passive solar design would limit the space that needs heating to as little as necessary.

- The final component to remember in passive solar design is the overall orientation of your design elements. Do you know which way the sun comes up and goes down and shines all day long? You must know from which direction the sun shines so you can place your walls and windows intended to capture the sunlight facing in that direction. Also, if you know the regular direction of cold wind, it is smart to position and design the house to block or divert that wind, to minimize it cooling your house (which makes heating it more difficult).

- One of the most unique and fun aspects about passive solar heating is that it can be done in almost an unlimited amount of ways. So engineers who design passive solar heating systems can be as creative as they want!

Day 2- Group Work	1. Distribute Design Challenge Handout Review and do a Q&A. 2. Have students work in groups to brainstorm and come up an official design sketch on paper. Conference with each group to make sure they reach the design criteria. Give students mini deadlines for building, conducting tests and completing an analysis.

Day 3&4- Group Work	1. Follow procedure on Teacher Testing Steps Handout. Students work to conduct trials, collect data and refine design. Handout Analysis and Results Worksheet

Day 5 Wrap-Up	1. Group Presentations Students present their models and make sense of the data collected with specific focus on -Design -Hypotheses -Variables -Trials conducted -Data Collected -Graph Analysis -Conclusion

Rubric

	4	3	2	1
Variables	Independently identified and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables).	Independently identified which variables were going to be changed (independent variables) and which were going to be measured (dependent variables). Some feedback was needed to clearly define the variables.	With adult help, identified and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables).	Adult help needed to identify and define almost all the variables.
Hypothesis	Independently developed an hypothesis well-substantiated by a literature review and observation of similar phenomena.	Independently developed an hypothesis somewhat substantiated by a literature review and observation of similar phenomena.	Independently developed an hypothesis somewhat substantiated by a literature review or observation of similar phenomena.	Needed adult assistance to develop an hypothesis or to do a basic literature review.
Data	Data was collected several times. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. Adult assistance was needed to clearly summarize what was discovered.	Data was collected only once and adult assistance was needed to clearly summarize what was discovered.
Conclusion	Student provided a detailed conclusion clearly based on the data and related to previous research findings and the hypothesis statement(s).	Student provided a somewhat detailed conclusion clearly based on the data and related to the hypothesis statement(s).	Student provided a conclusion with some reference to the data and the hypothesis statement(s).	No conclusion was apparent OR important details were overlooked.

Differentiation

Encourage students to do more research on passive solar heating techniques incorporate what they find in their model houses.

References

http://www.teachengineering.org/view_activity.php?url=collection%2Fcub_%2Factivities%2Fcub_housing%2Fcub_housing_lesson05_activity1.xml&state=New+York#attachments